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APPLICATION

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TITLE: PULSED DEPLOYMENT OF A CABLE THROUGH A CONDUIT LOCATED IN A WELL

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PULSED DEPLOYMENT OF A CABLE THROUGH A CONDUIT LOCATED IN A WELL

CROSS-REFERENCE TO RELATED APPLICATION

[001] This claims the benefit under 35 U.S.C. § 119(e) of U.S. Provisional Application Serial No. 60/393,488, entitled "GAS DEPLOYMENT OF A CABLE THROUGH A CONDUIT LOCATED IN A WELL," filed July 3, 2002.

BACKGROUND

[002] The invention generally relates to the deployment of a cable in a conduit by use of fluid drag. More particularly, the invention relates to such deployment of a fiber optic cable in an oil and gas well in which gas or liquid is pulsed to create the fluid drag.

[003] As disclosed in EP 108,590 and others, it is known in the prior art to install a fiber optic cable in a conduit by passing a fluid through the conduit at a high enough velocity to propel the cable along the conduit by way of fluid drag. Also, as disclosed in US Reissue 37,283, this deployment technique has even been used to deploy fiber optic cable within a conduit located inside of an oil and gas well.

[004] In some cases, particularly at high temperatures and/or high pressures, the use of liquid as the propelling fluid leads to increased attenuation in the fiber optic cable. This situation is alleviated by the use of gas as the propelling fluid. However, depending on the relative cross-sectional areas of the cable and conduit, the use of gas as the propelling fluid greatly diminishes, if not stops, the rate of deployment of the cable.

[005] Thus, there exists a continuing need for an arrangement and/or technique that addresses one or more of the problems that are stated above.

SUMMARY

[006] A system and method for deployment of a cable, such as a fiber optic cable, through a conduit located in a well. A fluid is pulsed through the conduit, which pulse intermittently forces the cable to pass through the conduit. The cable may include at least one measurement location

to measure a parameter of interest within the well. The fluid pulsing technique may also be used to deploy the cable in a conduit adapted to be located in other locations.

BRIEF DESCRIPTION OF THE DRAWING

[007] Fig. 1 is a general schematic of the system used to deploy a cable into a conduit.

[008] Fig. 2 is a more detailed view of one embodiment of the system.

[009] Fig. 3 is a schematic of the system used to deploy a cable into a conduit located within an oil and gas well.

DETAILED DESCRIPTION

[0010] Figure 1 shows a system 10 used to propel at least one cable 12 into a conduit 14. The cable 12 may include a sensor 16 for sensing a physical parameter. Alternatively, the cable 12 may include multiple sensing locations along its length. An interrogation unit 18 is functionally attached to the cable 12 and interrogates the signals sent through the cable 12 from the sensor 16 or sensing locations in order to make a measurement of the parameter of interest. A cable installation unit 20 installs the cable 12 within the conduit 14 and includes a fluid unit 22 for propelling the fluid into the conduit 14. The installation unit 20 may also include a lead-in section 24 for providing a distance to enable sufficient fluid drag on the cable 12 as it enters the conduit 14. The cable 12 is shown wound up on a drum 26. The cable 12 and sensor 16 may be deployed to a remote location 5, such as an oil and gas well.

[0011] The cable 12 may be one or more optical fiber cables. These may be hermetically sealed with carbon coating, may have high temperature coatings such as polyimide, or silicone or polytetrafluoroethylene, or may have combinations of these coatings. The cable 12 may also be acrylate-coated fibers.

[0012] The sensor 16 or sensing locations on cable 12 may be one or more optical fiber sensors. The sensors may include sensors for measuring temperature, distributed temperature, pressure, acoustic energy, electric current, magnetic field, electric field, flow, chemical properties, or a

combination thereof. The cable 12 itself may act as the sensor, such as taught by US Patent Nos. 4,823,166 and 5,592,282 issued to Hartog wherein the sensor is an optical fiber that acts as a distributed temperature sensor.

[0013] The interrogation unit 18 may be instrumented electronics. The interrogation unit 18 may be an electro-optic electronic readout system suitable for interrogating the appropriate optical fiber cable and sensors and may include one or more optical fiber amplifiers.

[0014] The interrogation unit 18 need not be connected to the cable 12 while the cable 12 is pumped through the conduit 14 to the remote location 5. In many instances it is preferable to remove the installation unit 20 once the cable 12 is properly located at the remote location 5, form a seal around the cable 12 where it enters or exits conduit 14, and then connect cable 12 to the interrogation unit 18 with a separate cable specially designed for surface cabling.

[0015] The conduit 14 may be high-pressure tubing with an inside diameter and pressure rating to make it suitable for deploying the cable 12 and sensor. When deployed in an oil and gas well, the conduit 14 may be steel hydraulic control line commonly used in the oil and gas industry having an external diameter of 1/8" to 3/4". Alternatively, the conduit 14 may be coiled tubing commonly used in the oil and gas industry having an external diameter of 3/4" to 2".

[0016] In one alternative embodiment, the cable 12 is first pumped through the conduit 14, and the conduit 14 is then properly disposed in the remote location 5.

[0017] For this invention, fluid unit 22 propels a fluid into the conduit 14, but it does so by pulsing the fluid into the conduit 14. The fluid may be a liquid or a gas, or a combination thereof. The fluid unit 22 may include at least one gas bottle, a gas compressor, a fluid pump, or a combination of any of these. The gas bottles may be manifolded together. The fluid may be any fluid that does not adversely react with the cable 12 (such as by causing optical cable attenuation) or surrounding environment. Adequate gas types include nitrogen, air, and gases from the family of inert gases (argon, helium, neon, xenon, krypton, radon). Adequate liquid types include water and other appropriate liquids.

[0018] Figure 2 shows one embodiment of the system 10. An orifice 28, which can be a capillary, enables the passage of the cable 12 from the drum 26 to the interior of the installation unit 20. Fluid unit 22 injects the fluid through passage 32 and into lead-in section 24 to propel cable 12 therein and within conduit 14. The pressure provided by fluid unit 22 may act against orifice 28 and may therefore also act to somewhat prevent the ingress of the cable 12 from the drum 26 into the installation unit 20. In order to ensure that such ingress is not prevented, a governor 30 may be inserted within installation unit 20 in order to amplify the force provided to cable 12 by the fluid in the direction of the remote location 5. The force amplification by the governor 30 ensures that the force in the direction of the remote location 5 is greater than the force that may act against the orifice 28; thus, the cable 12 is propelled by the fluid unit 22 in the correct direction.

[0019] As previously discussed, the fluid unit 22 pulses fluid through passage 32 and into lead-in section 24. It has been found that, depending on the fluids used as the propelling medium, forward movement of the cable 12 tends to stop after a short distance if the fluid is injected in a continuous manner. The stoppage is perhaps caused by the cable 12 sticking to the inside wall of the conduit 14. If the fluid injection is pulsed, each fluid pulse lifts and propels the cable 12 a distance farther down the conduit 14. Each fluid pulse creates a new pressure differential, which intermittently carries the cable 12 forward.

[0020] Each fluid pulse lasts a specific duration of time, which may be a function of the length of conduit, after which time the fluid injection is stopped. The pressure within each fluid pulse may also be varied. For instance, fluid may be injected at a specific pressure initially and thereafter at a higher pressure until the end of the fluid pulse. The initial lower pressure provides enough time for a substantial amount of the cable 12 to be within or immersed in the fluid pulse. This initial lower pressure induces the movement of the cable 12. The subsequent higher pressure is then able to increase the rate of movement of the cable 12 until the end of the fluid pulse. The variation of pressure during a fluid pulse is specially useful when there is a limited amount of compressed fluid on hand, specially if there is a limited amount of higher pressure compressed gas on hand.

[0021] If the fluid is a gas, in order to minimize the amount of liquid present in the interior of the conduit 14 (which liquid may lead to the cable 12 sticking to the inside wall of the conduit 14), the conduit 14 may be prepared prior to the deployment of the cable 12 within the conduit 14. The preparation of the conduit 14 can be specially useful in the conduits 14 used in oil and gas applications, since such conduits are normally pressure tested by the manufacturer with either water or another liquid prior to shipment. The goal in the preparation of the conduit 14 is to clean the interior of the conduit 14 and to remove as much moisture and liquid from the interior of the conduit 14 as possible. One way to do this is to flush the conduit 14 with a rapidly evaporating solvent, such as isopropanol, methanol, or acetone. As the solvent is pumped through the conduit 14, it will clean the interior diameter of the conduit 14. In addition, the solvent will evaporate rapidly leaving the interior wall of the conduit 14 clean and very dry. As previously stated, the cable 12 will tend to move a farther distance down the conduit 14 with each fluid pulse if the interior wall of the conduit 14 is clean and dry.

[0022] If the fluid is a liquid, in order to minimize the amount of liquid that is not miscible with the deployment fluid that is present in the interior of the conduit 14 (referred to as "Non-miscible liquid")(which Non-miscible liquid may lead to the cable 12 sticking to the inside wall of the conduit 14), the conduit 14 may be prepared prior to the deployment of the cable 12 within the conduit 14. The preparation of the conduit 14 can be specially useful in the conduits 14 used in oil and gas applications, since such conduits are normally pressure tested by the manufacturer with a Non-miscible liquid prior to shipment. The goal in the preparation of the conduit 14 is to clean the interior of the conduit 14 and to remove as much Non-miscible liquid from the interior of the conduit 14 as possible. One way to do this is to flush the conduit 14 with a rapidly evaporating solvent, such as isopropanol, methanol, or acetone. As the solvent is pumped through the conduit 14, it will clean the interior diameter of the conduit 14. In addition, the solvent will evaporate rapidly leaving the interior wall of the conduit 14 clean and very dry. As previously stated, the cable 12 will tend to move a farther distance down the conduit 14 with each fluid pulse if the interior wall of the conduit 14 is clean and dry.

[0023] Prior to passing the solvent into the conduit 14 and particularly useful in oil and gas applications, a gas may be injected to first displace any of the standing water or liquid within the conduit 14. Moreover, once the solvent is passed into the conduit 14, the solvent may be left in

the conduit 14 for a period of time, such as 20-30 minutes for example. The solvent may be purged out of the conduit 14 by passing gas through the conduit 14.

[0024] Figure 3 shows the use of the system 10 in an oil and gas well 100. The well 100 may include a casing 102, a well head 104, a length of production tubing 106 through which oil flows from a reservoir 108, and a packer 110 for isolating the pressure from the reservoir from the surface. In one embodiment, conduit 14 is strapped to the production subbing 106 using straps 112. The conduit 14 passes down the well 100 and may pass through packer 110, such as by packer penetrators and/or feedthroughs. The conduit 14 may be configured in a U-shape so that the conduit 14 turns around at U-bend 114 and passes back up the well 100 again. Conduit 14 enters and exits wellhead 104 via ports 116.

[0025] In use, the conduit 14 may be installed in the well 100 as the production tubing 106 is being deployed in the well. Once the installation of the other components of the well 100 is complete, the conduit 14 may be prepared as previously disclosed, such as by purging any standing liquid in the conduit 14 with gas, passing a solvent through the conduit 14, letting the solvent stand in the conduit 14 for a period of time, and purging the solvent from the conduit 14 with gas. Once the conduit 14 is clean and dry, the cable 12 is installed within the conduit 14 by connecting the system 10 to conduit 14 and pulsing the cable 12 through conduit 14 using fluid (as previously disclosed). Any fluids can be collected at the far end 15 of cable 14 by a vessel 70. Alternatively, the far end 15 can be routed back to the system 10. The cable 12 is deployed within the well 10 so that it is adequately positioned to enable the sensor 16 or sensor location to measure the parameters of interest.

[0026] In another embodiment, instead of having a return line or U-shape, the conduit 14 is single-ended and includes a check valve so that the cable 14 can be deployed hydraulically therein. The check valve allows the deployment fluid to be released into the well 100 while it is pressurized (during deployment) but thereafter seals the conduit 14.

[0027] In another embodiment, the cable 12 is pumped into the conduit 14 at the surface, and the conduit 14 with the cable 12 already therein is deployed into the well 100.

[0028] Following installation, the conduit 14 external to the well 100 may be removed taking care not to sever the cable 12, and the cable 12 is then connected to the interrogation unit 18. The cable 12 and sensor 16/sensor locations can then be used to measure the parameter of interest.

[0029] As previously disclosed, depending on the sensors used, a variety of parameters may be measured within well 100, including temperature, distributed temperature, pressure, acoustic energy, electric current, magnetic field, electric field, flow, chemical properties, or a combination thereof. In one embodiment, the cable 12 is a fiber optic cable and together with the appropriate interrogation unit 18 comprises a distributed temperature system which measures distributed temperature along the length of the cable 12 (such as Sensor Highway Limited's DTS units). Although different techniques can be used, in one technique called optical time domain reflectometry pulses of light at a fixed wavelength are transmitted from the unit 10 down the fiber optic cable 12. Light is back-scattered from every point along the cable 12 and returns to the interrogation unit 18. Knowing the speed of light and the moment of arrival of the return signal enables its point of origin along the cable 12 to be determined. Temperature stimulates the energy levels of the silica molecules in the cable 12. The back-scattered light contains upshifted and downshifted wavebands (such as the Stokes Raman and Anti-Stokes Raman portions of the back-scattered spectrum) which can be analyzed to determine the temperature at origin. In this way the temperature of each point in the cable 12 can be calculated by the interrogation unit 18, providing a complete temperature profile along the length of the cable 12. This general fiber optic distributed temperature system and technique is known in the prior art. The U-shaped return line may provide enhanced performance and increased spatial resolution to the temperature sensor system.

[0030] Although the oil and gas installation has been described with the conduit 14 attached to a production tubing 106, it is understood that conduit 14 (and therefore the fluid pulsing deployment technique) may be deployed inside a well in a variety of manners (such as by itself or cemented behind a well casing), each of which is within the scope of this invention. Furthermore, the use if this invention is applicable to all types of wellheads and well locations, including subsea wells.

[0031] In one embodiment, in order to further decrease the chance of fiber optic cable attenuation, once the cable 12 is properly deployed and located within the conduit 14, the pressure caused by the fluid injection within the conduit 14 may be released. The conduit 14 is at atmospheric pressure at that point. An inert displacement gas with a greater specific weight than ambient atmospheric gas may help to ensure that no or fewer unwanted molecules pass into the core of the fiber optic cable 12 (which will tend to lead to attenuation).

[0032] In another embodiment, fluid pressure is maintained in the conduit 14 to ensure that flow is outwardly from the conduit 14 in the event there is a leak in the conduit 14. If flow is inwardly into the conduit 14, then well fluids (including liquids) may enter the conduit 14 and come into contact with the cable 12, which occurrence may damage the cable 12. Thus, in this embodiment, the fluid pressure maintained in the conduit 14 should be higher than the pressure in the exterior of the conduit 14. This pressure should also be maintained despite the presence of a leak; therefore, fluid may need to be continuously injected to maintain this pressure.

[0033] In any embodiment, different fluids (those fluids as previously described) may be used during the process. For instance, in the embodiment described in the previous paragraph in which fluid pressure is maintained in the conduit 14, cable 12 may be deployed with one fluid (for example nitrogen), and the fluid pressure may be held with another fluid (for example argon).

[0034] As previously described, the conduit 14 is first deployed in the well 100 and then the cable 12 is installed in the conduit 14. In another embodiment, the cable 12 is first installed in the conduit 14 (as previously described) on the surface and then the conduit 14 (with the cable 12 disposed inside) is deployed in the well 100. In this embodiment, pressure in the interior of the conduit 14 may be maintained at an elevated pressure (as previously disclosed) during the deployment of the conduit 14 in the well 100.

[0035] It is understood that more than one cable 12 may be concurrently passed through conduit 14.

[0036] Although described for use in an oil and gas well, the deployment method described herein may also be used in other non-oil and gas well applications. Thus, at least one cable 12

may be pulsed into a conduit 14 (that is not adapted to be located in an oil and gas well), as previously described, to a remote location. Remote locations may comprise pipelines (including subsea pipelines), tunnels, and power lines. And, the cable 12 may provide measurements of parameters of interest along the conduit, as previously described.

[0037] While the invention has been disclosed with respect to a limited number of embodiments, those skilled in the art, having the benefit of this disclosure, will appreciate numerous modifications and variations therefrom. It is intended that the appended claims cover all such modifications and variations as fall within the true spirit and scope of the invention.